

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN MECHANISMS

(71) I, JOHN HENRY BREMS, a citizen of the United States of America, of 32867, White Oaks Trail, Birmingham, State of Michigan 48010, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to mechanisms and is particularly concerned with indexing systems.

The present invention provides an intermittent reversible indexing system having a rotary input and a rotary output, with variable kinematic characteristics comprising:

- (a) a frame,
- (b) a circular reaction member mounted on said frame and concentric with a first axis,
- (c) a first rotatable member mounted for rotation on said frame and about said first axis,
- (d) a second rotatable member mounted for rotation on said first rotatable member about a second axis displaced from said first axis, said second rotatable member being arranged in tangential driving engagement with said circular reaction member,
- (e) an eccentric member mounted on said second rotatable member and provided with a third axis displaced from said second axis,
- (f) an output member mounted for rotation on said frame about a fixed fourth axis displaced from said first axis, said output member being arranged in driving engagement with said eccentric member so as to rotate in a fixed direction dependent upon the direction of rotation of the first rotatable member, and
- (g) input means for driving one of said rotatable members.

The invention is described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal section through a typical system embodying the invention.

Figure 2 is a transverse section taken on the line 2—2 of Figure 1.

Figure 3 is a transverse section taken on the line 3—3 of Figure 1.

Figure 4 is a schematic kinematic drawing illustrating parameters and variables of the system.

Figure 5 is a series of curves showing the output velocity as a function of input angle for an illustrative set of parameters.

Figure 6 is a series of curves showing the output acceleration as a function of input angle for the same set of illustrative parameters as used in Figure 5.

Figure 7 is a series of curves showing the output velocity as a function of input angle for a second set of illustrative parameters.

Figure 8 is a series of curves showing the output acceleration as a function of input angle for the same set of illustrative parameters as used in Figure 7.

Figure 9 is a schematic drawing illustrating the change of output angle with a shift of offset of the output axis.

Figure 10 is a longitudinal section through an alternate embodiment of the invention.

Figure 11 is a transverse section taken on the line 11—11 of Figure 10.

Figure 12 is an enlarged detailed view showing fastening means for a cover plate shown in Figure 11.

Figure 13 is a transverse section taken on the line 13—13 of Figure 12.

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Referring to Figures 1, 2 and 3, a case 2 supports a stationary shaft 4 on which in turn is mounted a stationary reaction member in the form of a sun gear 6. A planetary carrier assembly is made up of a plate 8 and a housing 10 bolted thereto. This planetary carrier 8, 10 is mounted on the stationary shaft 4 through bearings 12 and 14 and is rotatable about an axis A_0 . The periphery of the plate 8 is formed into a gear suitable for meshing with an input gear 16 mounted on a shaft 18 which is rotatable in bearings 20 and 22 mounted in a housing 24 bolted to the case 2.

The shaft 18 is rotated by some external drive source such as a reversible electric motor and gear reducer with a suitable brake (not shown) to be utilized at the end of the stroke. Rotation of the shaft 18 causes the planetary carrier 8, 10 to rotate about the fixed axis A_0 .

A planetary gear 26 suitably formed to mesh with the sun gear 6 is mounted on a planetary shaft 28 which in turn is mounted on the planetary carrier 8, 10 through bearings 30 and 32. The planetary gear 26 is rotatable about a movable axis A_1 as the planetary carrier 8, 10 rotates about the axis A_0 .

A support plate 34 is mounted on the planetary shaft 28 and has projecting therefrom an eccentric shaft 36 whose axis A_2 is displaced from the axis A_1 . A slide block 38 is rotatably mounted on the eccentric shaft 36; this slide block 38 in turn is slidably movable in a slot 40 of an output spider 42 (Figure 2). This output spider 42 is mounted on an output shaft 44 which is rotatable in bearings 46 and 48 mounted in a case cover 50 fastened by bolts (not shown) to the case 2. The shaft 44 and output spider 42 are rotatable about an output axis A_3 displaced from the primary axis A_0 .

There are a variety of kinematic and mechanical benefits which accrue from the displacement of the output axis A_3 from the primary axis A_0 as will be evident from the kinematic analysis below. It can be seen that as the planetary carrier 8, 10 rotates about the axis A_0 and the planetary shaft 28 is driven about the moving axis A_1 , the eccentric shaft 36 and its axis A_2 move in an epitrochoidal or epicycloidal path, depending on the amount of displacement of the axis A_2 from the axis A_1 . Provided only that the axis A_2 lies within the path of the axis A_0 , the eccentric shaft 36 and slide block 38 cause the output spider 42 and output shaft 44 to rotate about the axis A_3 .

Referring to the schematic kinematic diagram shown in Figure 4, the following quantities will be defined:

ϕ = the angle of rotation of the gear 26 about its axis A_1 , i.e. the angle between the line joining the axes A_0 , A_1 , and the line joining the axes A_1 , A_2 , from 0° to 360° per cycle of the mechanism. This angle, is referred to hereinafter as the input angle.

R = the pitch radius of the sun gear 6

ϕ = the angle of rotation of the output shaft 44 which has a range of

$$0-360^\circ$$

R

per cycle of the mechanism

K = the distance from the axis A_1 to the axis A_2 .

The pitch radius of the planetary gear 26 is arbitrarily defined as 1 unit and a master radial line is defined as that radial line extending from the centre of the sun gear 6, i.e. the axis A_0 , to the centre of the planet gear 26, i.e. the axis A_1 , with the planet gear 26 so positioned that the axis of the eccentric shaft 36, the axis A_2 , lies between the axes A_0 and A_1 . The dashed outline of the shaft 36 in Figure 3 shows this arrangement of the gears 6 and 26 and the shaft 36.

The line joining the primary axis A_0 and the output axis A_3 has a length E and makes an angle δ with the master radial line. The distance E may be defined in terms of E_1 which is the length of a line parallel to the master radial line; and E_2 which is the length of a line perpendicular to the master radial line.

After the planet 26 has rotated through an angle θ with respect to the line joining the axes A_1 and A_0 the planet gear 26 reaches the position shown in solid lines in Figure 4. It can be seen that:

$$\Psi = \tan^{-1} \left(\frac{K \sin \theta}{R+1-K \cos \theta} \right) \quad \phi = f(\theta) \quad (1)$$

and

$$Z = \sqrt{(K \sin \theta)^2 + (R+1-K \cos \theta)^2} \quad (2)$$

By summing angles about the axis A_0 :

$$\beta = 180 - \delta + \frac{\theta}{R} - \psi \quad (3)$$

By using the Cosine Law:

$$W = \sqrt{E^2 + Z^2 - 2EZ \cos \beta} \quad (4)$$

5 By again using the Cosine Law:

5

$$\gamma = \cos^{-1} \left(\frac{W^2 + Z^2 - E^2}{2WZ} \right) \quad (5)$$

By summing interior angles in the triangle defined by the axes A_0 , A_2 , A_3 :

$$\epsilon = 180 - \gamma - \beta \quad (6)$$

It can be seen that the value of ϵ when θ is 0, defined as ϵ_0 , is:

$$10 \quad \epsilon_0 = \tan^{-1} \left(\frac{R + 1 + E_1 - K}{E_2} \right) - \tan^{-1} \left(\frac{E_1}{E_2} \right) \quad (7) \quad 10$$

And by summing angles about the axis A_3 :

$$\phi = \epsilon_0 - \epsilon \quad (8)$$

15 It can be seen that a definite functional relationship exists between the output angle ϕ and the input angle θ ; that is, for every value of the angle θ there exists a calculable value of the angle ϕ and therefore

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$$\phi = f(\theta)$$

20 To express this functional relationship explicitly is laborious and complex; subsequently to differentiate such an explicit expression to obtain velocity by the methods of classical calculus and then to differentiate again to obtain acceleration again by the methods of classical calculus is exceedingly complex.

20

The solutions may be obtained with relative ease by numerical methods using a programmable calculator or computer. For each value of θ , it is possible to calculate a value of ϕ using the equations (1) to (8), with R , K , E_1 and E_2 as parameters. First and second derivatives may be obtained using standard numerical techniques.

25 Using such numerical methods, the graphs of the kinematic characteristics shown in Figures 5, 6, 7 and 8 were obtained. Figures 5 and 6 represent the kinematic behavior of a system in which the radius R of the sun gear 6 is set equal to 1; therefore, the sun gear 6 and the planetary gear 26 are equal in size, and a given index cycle consists of a 360° output movement of the output spider 42 and a movement of 360° of the planetary carrier 8, 10. The axis A_2 of the eccentric shaft 36 lies on the pitch line of the planetary gear 26 and the value of K is therefore 1.

25

30 The velocity of the output relative to the velocity of the input may be taken as

30

$$\frac{d\phi}{d\theta}$$

35 and this velocity for three different values of E_1 , with $E_2=0$, is shown in Figure 5. Because of obvious symmetry when $E_2=0$, the curves are only plotted for a 180° input span. It will be noted that for all three values of E_1 , the velocity of the output has a value of 0 when the input angle is 0 and reaches a maximum value when the input angle is 180° . Therefore, for rotation of the carrier 8, 10 at a constant angular velocity, the output will stop or dwell once during each cycle.

35

The acceleration of the output relative to the input,

$$\frac{d^2\phi}{d\theta^2}$$

for the same B_1 parameters as those used for Figure 5 are shown in Figure 6. It will be noted that the acceleration reaches 0 at input angles of 0 and 180°. It is evident from Figures 5 and 6 that it is possible to modify both the velocity and acceleration characteristics of the indexing system to a significant degree by controlling the magnitude of B_1 alone while B_2 is 0.

When B_2 has a value other than 0, such symmetry no longer exists; this is illustrated in Figures 7 and 8. For these figures, $R=1$ and $K=1$ as for Figures 5 and 6 and $B_1=.5$ for all curves which are now presented for the full 360° input span. In Figures 7 and 8, the curves marked 0 ($B_2=0$) are identical with the curves $B_2=.5$ in Figures 5 and 6. When B_2 is .5 a significant alteration in the velocity and acceleration characteristics will be noted.

The kinematic behavior of the system for an illustrative set of parameters is shown by the curves of Figures 5 to 8. It will be understood that these are sample characteristics only. By a judicious and knowledgeable choice of the governing parameters R , K , B_1 and B_2 , one of a wide variety of specific mechanisms may be designed to suit a given application requirement.

Figure 9 shows another important practical attribute of having the output axis A_3 non-coincident with the primary axis A_0 , which is that the output index angle may be varied over a small but useful range by a small adjustment in the offset or distance between the primary axis A_0 and the output axis A_3 .

Referring to Figure 9, the planet gear 26 is shown in two positions: a first or starting position shown in dotted lines; and a second or stopping position shown in solid lines after the planet gear 26 has rotated through one revolution clockwise about its own axis A_1 and has moved slightly less than 360° clockwise about the sun gear 6. It is obvious that to achieve this situation, the radius of the sun gear 6 is slightly larger than the radius of the planet gear 26. It will also be seen that to achieve this movement of the planetary gear 26, the planetary carrier 8, 10 rotates clockwise about the axis A_0 through an angle θ_1 with reference to Figure 9.

If the output axis A_3 is at the position shown in Fig. 9, it can be seen that the total output index movement is represented by the angle ϕ' ; if the output axis is now moved to some new position illustrated by the axis A_3' , the total output index movement is shown by the angle ϕ'' , where the angle ϕ'' is different from the angle ϕ' .

Therefore, it may be stated that for applications in which the planet gear 26 pitch radius is not an integral multiple of the sun gear 6 pitch radius, the output index angle may be varied through an adjustment of the distance between the primary axis A_0 and the output axis A_3 .

Practically such an adjustment movement may be easily attained by providing oversize holes or slots for fastening the case cover 50 to the case 2.

This characteristic is of particular value when the subject mechanism is used to drive a gear rack combination to accomplish a linear reciprocating indexing motion, and it is necessary to adjust the magnitude of the stroke to the precise needs of the application or to compensate for wear.

The embodiment shown in Figures 10 and 11 retains all of the essential elements of the invention but shows a different means of supplying the input power; it also illustrates one of a variety of ways of making the output axis adjustable with respect to the remainder of the mechanism.

Referring to Figures 11 and 12, the case 60 supports a stationary tubular shaft 62 on which is again mounted the stationary sun gear 6. A planetary carrier assembly is made up of a plate 64 and the housing 10 bolted thereto (bolts not shown) rotatable about the axis A_0 and shaft 62 on bearings 12 and 66. It will be noted that, in contrast to the plate 8, there are no gear teeth on the periphery of the plate 64, and that the previously shown input gear assembly has been eliminated.

The planetary gear 26 suitably formed to mesh with the sun gear 6 is again mounted on the planetary shaft 28 which in turn is mounted on the planetary carrier 64, 10 through bearings 30 and 32. The planetary gear 26 is rotatable about the movable axis A_1 and rotates about the axis A_1 as the planetary carrier 64, 10 rotates about the axis A_0 .

A cluster gear 68 is mounted on the planetary shaft 28 coaxial therewith and is also rotatable about the axis A_1 . An input gear 70 is suitably formed to mesh with

the gear 68; the gear 70 is mounted on the input shaft 72 and both are rotatable about the axis A_0 in bearings 74 and 76 mounted in the shaft 62. Input power is supplied to the shaft 72 by some external reversible power source. As the gear 70 rotates about the axis A_0 , it drives the gear 68 about the axis A_1 causing the gear 26 to move about the stationary sun gear 6. It will be noted that this is merely a different method of applying the input power to the gear 26 as compared to the embodiment of Figures 1, 2 and 3.

The eccentric shaft 36 is mounted on the gear 68 and again has an axis A_2 displaced from the axis A_1 . The remainder of the output system is substantially identical with that of Figures 1, 2 and 3.

The case cover 78 is modified to show clearly a way of providing adjustment means between the case 60 and case cover 78, thereby making the axis A_2 adjustable with respect to the axis A_0 . The case 60 is formed into a broad flange 80 at the interface with the case cover 78 which is fastened to it by a series of bolts 82, one of which is shown in Figures 12 and 13. Each bolt 82 clamps the case cover 78 to the case flange 80 through a thick oversize washer 84. Each receiving hole 86 in the case cover 78 is oversize relative to the bolts 82 to permit a significant movement of the case cover 78 with respect to the case 60. To accomplish an adjustment, all the bolts 82 are loosened, the case cover 78 is shifted to the desired new position, and all the bolts 82 are then retightened.

It will be understood that this system is illustrative only and that any of a wide variety of common adjustment systems could be utilized. It will be further understood that this illustrated adjustment system, or any other may be adapted to the embodiment of Figures 1, 2 and 3. As indicated the mechanism is reversible, this being accomplished by a reversible power input.

WHAT I CLAIM IS:—

1. An intermittent reversible indexing system having a rotary input and a rotary output, with variable kinematic characteristics comprising:

- (a) a frame,
- (b) a circular reaction member mounted on said frame and concentric with a first axis,
- (c) a first rotatable member mounted for rotation on said frame and about said first axis,
- (d) a second rotatable member mounted for rotation on said first rotatable member about a second axis displaced from said first axis, said second rotatable member being arranged in tangential driving engagement with said circular reaction member,
- (e) an eccentric member mounted on said second rotatable member and provided with a third axis displaced from said second axis,
- (f) an output member mounted for rotation on said frame about a fixed fourth axis displaced from said first axis, said output member being arranged in driving engagement with said eccentric member so as to rotate in a fixed direction dependent upon the direction of rotation of the first rotatable member, and
- (g) input means for driving one of said rotatable members.

2. An indexing system as claimed in claim 1 in which said circular reaction member comprises a gear, in which said first rotatable member comprises a planetary carrier, and in which said second rotatable member comprises a planetary gear mounted for rotation in said planetary carrier.

3. An indexing system as claimed in claim 2 in which the input means is adapted to drive said planetary carrier.

4. An indexing system as claimed in claim 1 or 2 in which said second rotatable member comprises a cluster gear and in which an input gear is mounted for rotation about said first axis in tangential driving engagement with said cluster gear.

5. An indexing system as claimed in any preceding claim in which said frame comprises a first frame member and a second frame member, said second frame member being adjustably mounted on said first frame member, said circular reaction member being mounted on the first frame member and said output member being mounted on said second frame member.

6. An indexing system as claimed in claim 5 in which said second frame member is adjustable on the first frame member radially relative to said first axis.

7. An indexing system as claimed in claim 5 or 6 including fastening means operably connecting said first and second frame members to prevent relative displacement of said frame members in a direction parallel to said first axis, said fastening

means being arranged to accommodate shifting of said frame members relative to each other in a plane perpendicular to said first axis whereby to change the spacing of said third and fourth axes.

5 8. An indexing system as claimed in any preceding claim in which said eccentric member comprises a shaft fixed on said second rotatable member. 5

9. An indexing system as claimed in any of claims 1 to 8 in which said eccentric member comprises a shaft projecting from the second rotatable member in a direction parallel to the fourth axis, said output member having a slot receiving said shaft in sliding relationship so that during driving of the output member by said shaft there is a sliding movement of said shaft in said slot radially of the fourth axis. 10

10. An indexing system constructed substantially as herein particularly described with reference to and as illustrated in Figs. 1 to 3; or Figs. 10 to 13 of the accompanying drawings. 10

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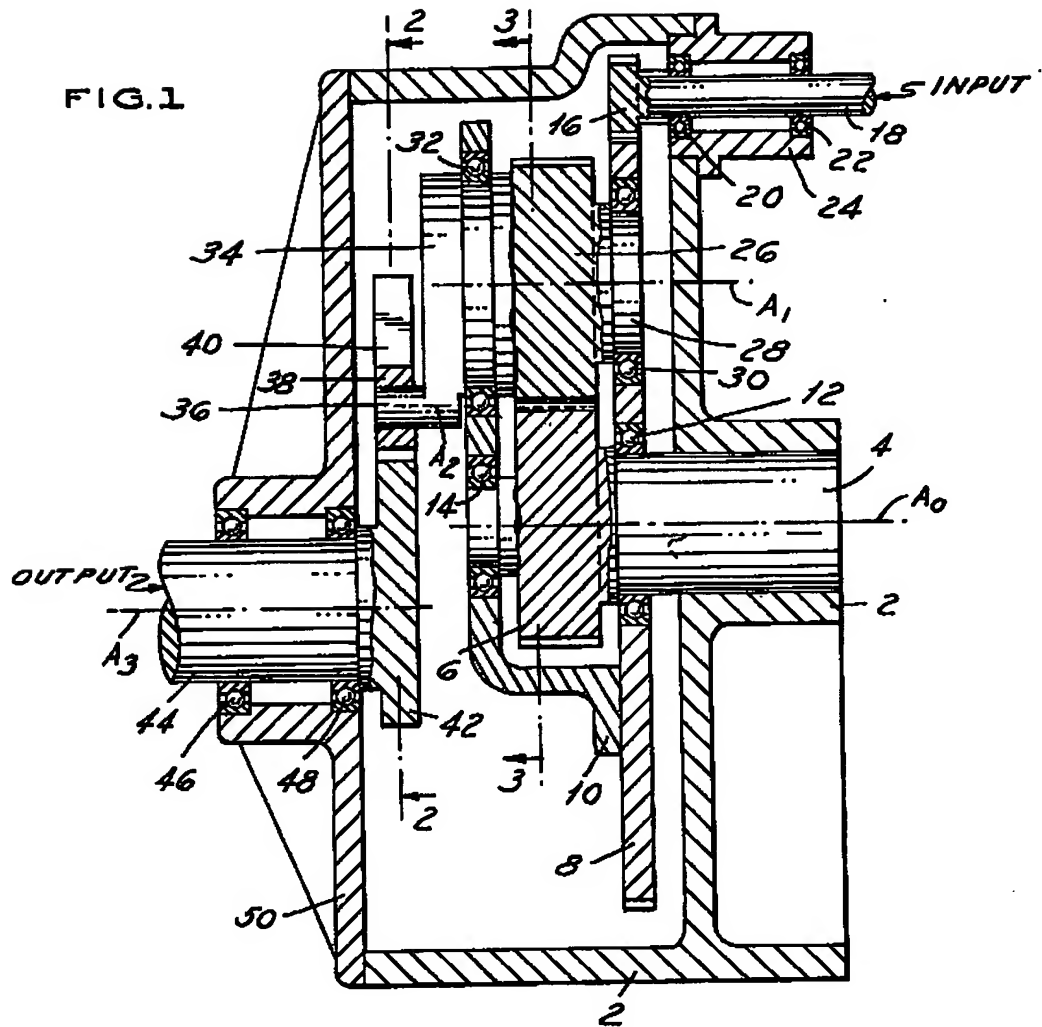


FIG. 9

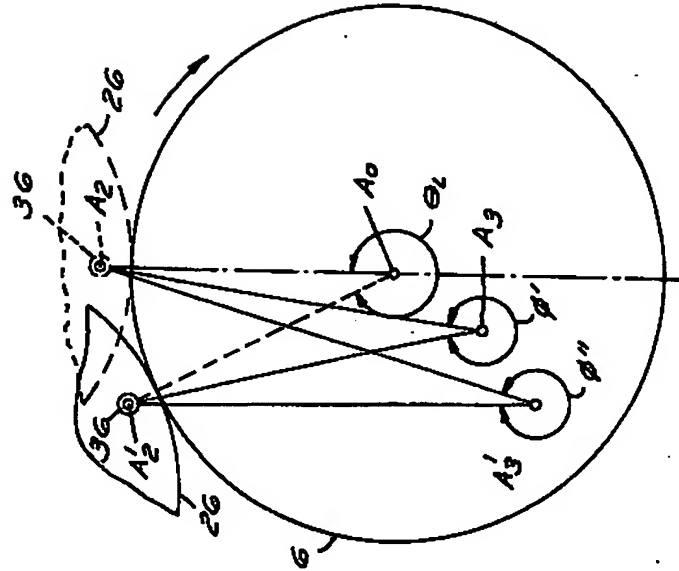


FIG. 3

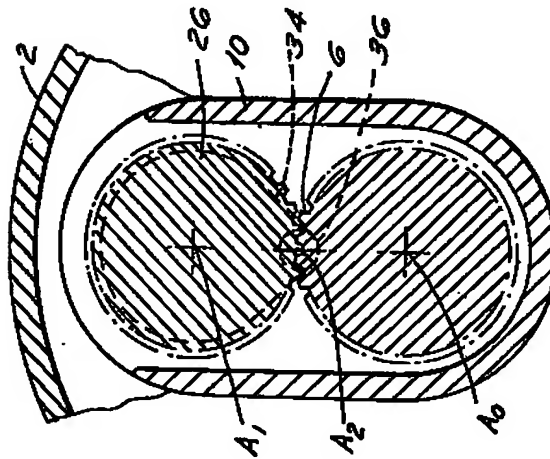


FIG. 2

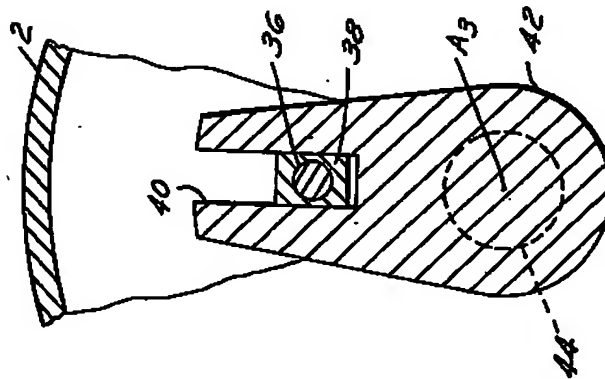


FIG. 5

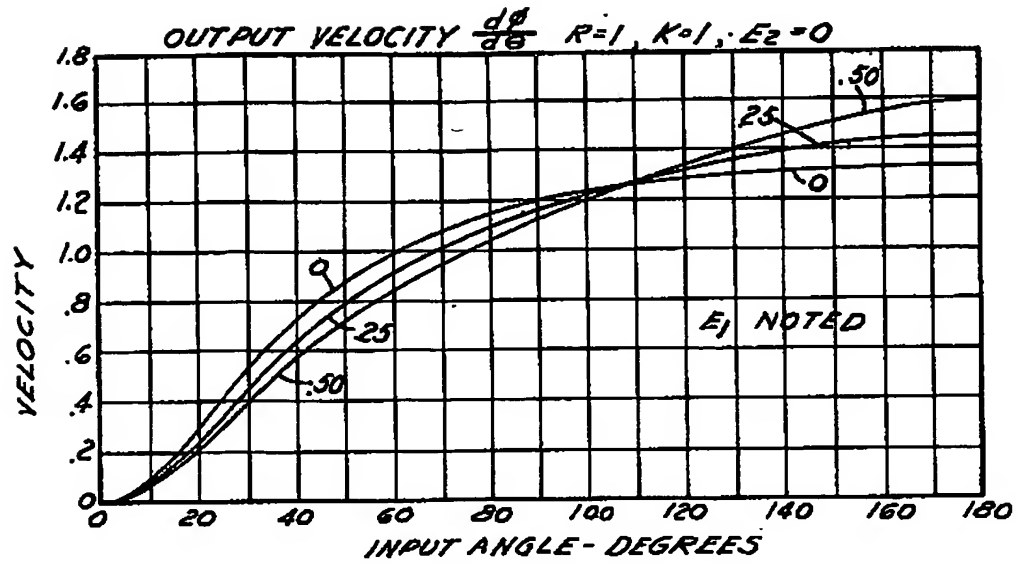


FIG. 6

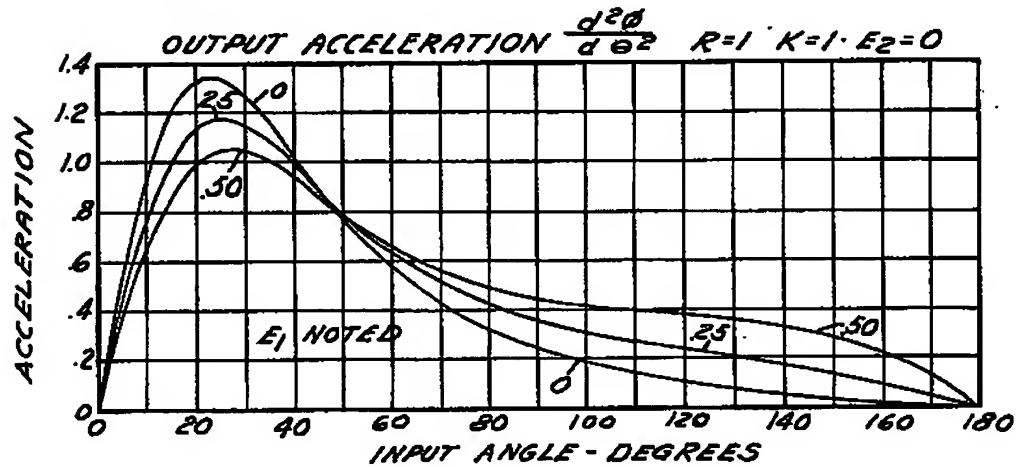


FIG. 7

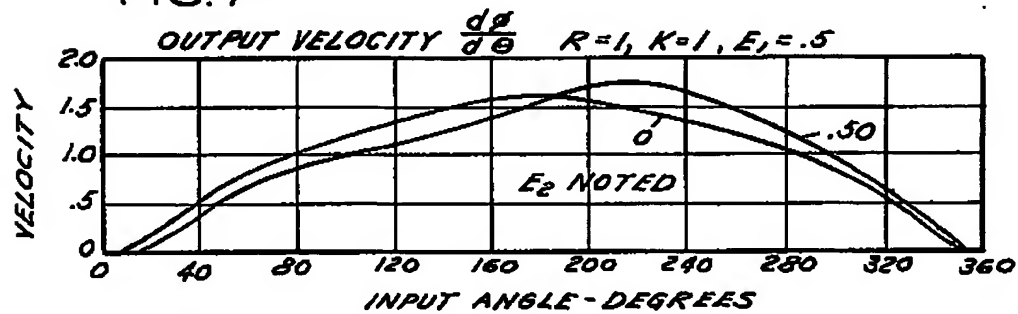


FIG. 8

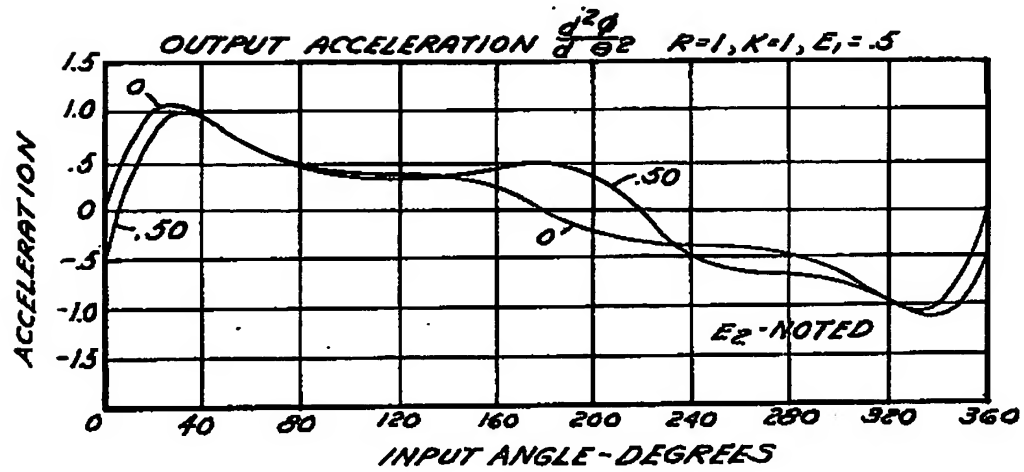


FIG. 12

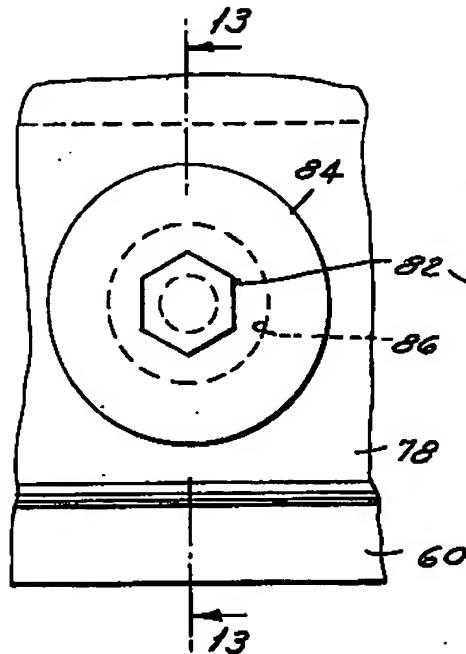
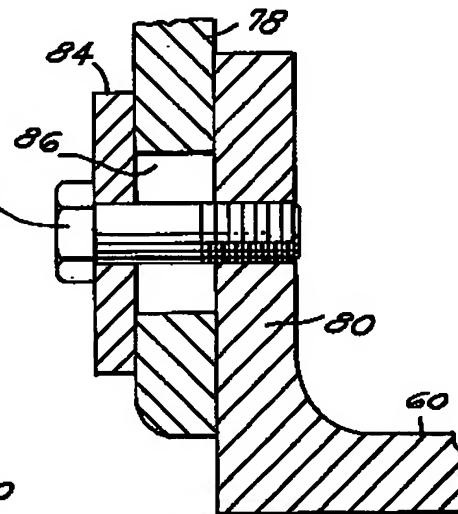
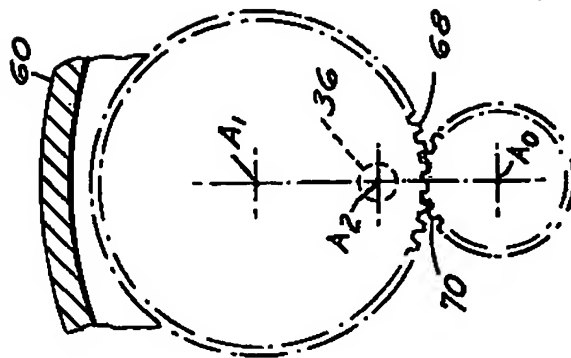


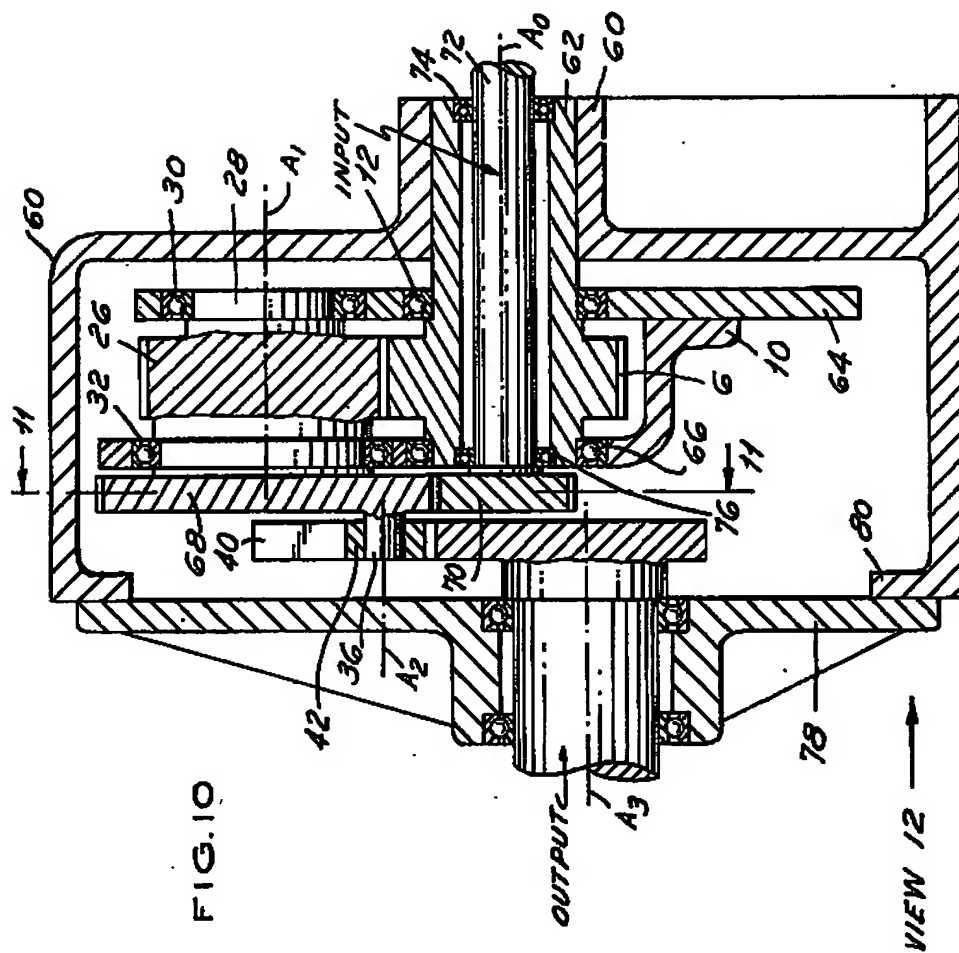
FIG. 13



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